Pest Management Grants Final Report

INTEGRATED WEED MANAGEMENT FOR LETTUCE: OPTIMIZED WEED MANAGEMENT INPUTS MADE ACCORDING TO SEASONAL FLUCTUATIONS IN WEED SEED GERMINATION

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Abstract

Herbicide options are limited in vegetables, therefore, our objective is to enhance the value of existing weed control inputs through study of weed biology. To detect shifts in the germination status of several weeds in the soil seedbank, soils at three vegetable fields were sampled periodically beginning March 1998 until the present and evaluated to determine the seed fraction that could readily germinate. Weed densities were counted periodically, to detect seasonal emergence patterns. Sixty to 90% of the annual bluegrass and southern brass buttons, respectively, emerged during winter. Common purslane and hairy nightshade peak emergence occurred in spring and summer with little emergence in fall and winter. However, burning nettle, common chickweed, common groundsel, henbit and shepherdspurse emerged continuously without distinct emergence peaks. Preliminary seedbank evaluations appear to confirm that seasonal fluctuations in germinability are related to seasonal weed emergence. Evaluations were conducted to determine if weed control in summer-planted lettuce could be maintained with reduced rates of bensulide and pronamide, and/or the brush hoe cultivator. Pronamide plus bensulide at 0.75 plus 3.0 pounds of active ingredient per acre (lb ai/A) provided excellent control of most weeds. The brush hoe cultivator removed weeds more efficiently than a standard cultivator.

Executive summary

Of all pesticides used in minor crops, herbicides are the most difficult to develop and register. Given the current regulatory status of many vegetable herbicides under the Food Quality Protection Act, the tolerances of some vegetable herbicides will likely be cancelled (Bell et al. 2000). Strategies to develop new vegetable herbicides or to produce genetically modified herbicide tolerant crops have severe limitations (Fennimore, 2000). Strategies that seek to preserve existing vegetable herbicides by minimizing the risks associated with their use have a great deal of potential value. One such strategy is to examine the biology of weeds to identify characteristics that will allow them to be managed more efficiently with less risk to human safety and the environment.

In the vegetable districts of the central coast of California lettuce is planted from December to August, and the weed spectrum during these long planting intervals varies by season. Approximately 60 and 90% of the annual bluegrass (*Poa annua*) and southern brass buttons (*Cotula australis*), respectively, emerged during winter. In contrast, both common purslane (*Portulaca oleracea*) and hairy nightshade (*Solanum sarrachoides*) had peak emergence in spring and summer with little emergence in fall and winter. On the other hand, burning nettle (*Urtica urens*), common chickweed (*Stellaria media*), common groundsel (*Senecio vulgaris*), henbit (*Lamium amplexicaule*) and shepherdspurse (*Capsella bursa-pastoris*) emerged all year round, thus lacking a distinct peak emergence period. Preliminary analysis of germinability, i.e., germination potential, from the soil seed bank evaluations of annual bluegrass, burning nettle, common chickweed, and shepherdspurse suggest that there is a relationship between seasonal changes in germinability and seasonal weed emergence. Management of weeds in vegetable crops is accomplished through a combination of herbicides, mechanical tillage and hand hoeing. Because herbicide options are increasingly more limited in vegetable crops, our principal research objective is to enhance the value of existing weed control inputs through greater understanding of weed germination characteristics. Soil samples from three vegetable fields were taken approximately every 45 days during March 1998 to March 2000 to detect shifts in the seed germinability of several weed species in the soil seed bank. These soil samples were placed in greenhouse trays and allowed to germinate for 45 days. At the completion of 45 days the weed seeds were extracted from the soil samples. After extraction the seeds were identified and counted under a microscope.

It was discovered that some weeds such as common purslane and hairy nightshade first emerge after 219 hours of 10°C and 452 hours of 4°C have accumulated. In the early season, before sufficient heat units have accumulated to induce common purslane and/or hairy nightshade emergence, weed control inputs can be directed on other weeds such as shepherdspurse that germinate all season. After the critical number of heat units has accumulated, weed control inputs should consider common purslane and hairy nightshade as well.

During the course of this research we have found an extremely effective cultivator, the brush hoe, that may allow some herbicide inputs to be replaced by mechanical, i.e., non-chemical, weed control inputs.

Introduction

Herbicide options are limited for California lettuce producers. Currently there are no postemergence herbicides registered for broadleaf weed control in lettuce, forcing growers to rely on preemergence herbicides. Decisions about preemergence herbicide choice and rate are made prior to weed emergence and based entirely on field history rather than predicted or observed weed pressure. Lettuce in the Salinas Valley is planted from late December until August. Prather (1997) observed that weed pressure in summer-planted lettuce is lighter than in spring-planted lettuce, and this observation suggests a seasonal cycle of weed emergence. The hypothesis to be tested is: a cycle of seasonal germinability exists in many of the common weed species of coastal California that is regulated by seasonal changes in air and soil temperatures. It may be possible to take advantage of this seasonal cycle in order to manage weeds with more precise weed control inputs, such as reduced herbicide inputs or a combination of reduced herbicide inputs and nonchemical inputs. There are currently no decision support tools available for weed management in coastal California lettuce. Knowledge of potential weed emergence from the seed bank would provide growers with more information on which to base weed management decisions. New cultivator designs such as the brush hoe cultivator have shown potential for use in vegetables (Colquhoin et al. 1999). Growers may decide to reduce or eliminate herbicide applications in lettuce if light weed populations can be reliably predicted and managed with improved mechanical cultivators.

Present objectives are to: 1) Develop an emergence model based on air and soil temperatures for common central coast weeds such as: burning nettle, common purslane, hairy nightshade, redroot pigweed and shepherdspurse, and 2) Develop a weed management program for lettuce based on reduced herbicide rates and improved cultivator designs.

Materials and methods

Objective 1. Three studies were established in Monterey County, CA, one on the Bengard farm near Chualar was initiated March 1998, and the second at the USDA/ARS Station near Salinas, CA was initiated April 1998 and the third site at the Spence farm 6 miles S. of Salinas was initiated April 1998. The Chualar study was seeded to broccoli 5.19.99 and cauliflower was transplanted into the Spence study on 4.27.99 and the Salinas study on 5.10.99 followed by a second crop, lettuce, seeded at Spence and Salinas on 8.13.99. At each study site, there are four plots with five fixed quadrats each laid out in a W-shaped pattern (Forcella et al. 1992). Four soil cores (5 cm wide by 7 cm deep) are taken from each quadrat, totaling 2,749 cm^3 per plot. The 20 cores are bulked by plot, placed in 26 X 26 cm trays, incubated in a growth chamber at 25/18°C (14-hour day10-hour night) (March 1998-20 September 1999) or prevailing soil temperatures and photoperiods (Table 1). At intervals of 14-16 days, weeds that emerge from the trays are identified, counted, and removed, the soil is then stirred. At the end of a 42-46 day period the remaining ungerminated seeds are extracted from the soil by washing through a 60 mesh screen (opening area of 0.048 mm^2). After air-drying, the elutriated samples are sieved through a 12 mesh screen (opening area of 4.752 mm^2) to get rid of the large mineral particles and then undergo a floatation procedure described by Ball and Miller (1989). The floating fraction is collected and inspected, under a 20 x dissection microscope, with regards to species and viability. Seed viability is determined by the pressure test as described in Forcella et al. (1992). Seeds that germinate during the growth chamber incubation period are considered germinable, i.e., have a high germination potential. The percentage of germinable seeds in the seed bank, by species, are being calculated using the equation $G = S / (S + U)$ where G is the germinable proportion, S is the number of seedlings that emerged in the growth chamber and U is the number of ungerminated viable seeds extracted from the soil. All field plots are sampled every 42-46 days throughout the year to detect seasonal changes in the percentage of germinable seeds. Soil temperatures are being monitored at the Hartnell and Spence sites throughout the study period. Field weed densities are counted and the weeds are removed periodically at the same fixed quadrats in each plot.

Degree day models for the emergence of common purslane and hairy nightshade were calculated using the procedure described in Wilen et al. (1996). Degree days were determined using the 'calculate degree days' option and the 'single sine' method available on the University of California, Davis IPM website[1]. Temperature thresholds for common purslane of 10°C and hairy nightshade of 4°C were based on the results published in Zimmerman (1977), and Roberts and Broddell (1983). The biofix date (start date) was set at 12.23.98, when the coldest air temperature occurred in the winter of 1998-99.

Objective 2. To evaluate the potential for reduced herbicide inputs, two on-farm weed control tests were conducted in 1999. Late-season lettuce studies were established near San Ardo on 8.10.99, and near Chualar on 8.12.99. The plot sizes were 18.6 m^2 (200 ft^2) at San Ardo and 11.6 m^2 (125 ft^2) at Chualar, and both trials were arranged in a randomized complete block design with 4 replications per treatment. Treatments included were: pronamide at 0.75 and 1.5 lb ai/A, bensulide at 3.0 and 5.0 lb ai/A, pronamide plus bensulide at 0.75 plus 3.0 lb ai/A and the untreated check. Weed density ratings were taken before lettuce thinning at both sites.

A study comparing the weed control efficacy of a brush hoe cultivator with a standard cultivator was initiated 8.13.99 in a field with high densities of shepherdspurse and moderate densities of common groundsel, and hairy nightshade. All cultural practices were typical for the Salinas valley including hoeing, thinning and cultivation. Lettuce was cultivated twice: first at the 4-leaf stage and second at the early rosette stage. Weed density counts were taken before and after each cultivation to evaluate the efficacy of the cultivators. Crop stand counts were taken

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[1] Available online at http://www.ipm.ucdavis.edu

before lettuce thinning, and the time to thin lettuce to commercial stand densities was also determined by timing a hoe hand as he thinned each plot. The data were analyzed using the SAS 'proc GLM' procedure.

Results

Field emergence. Southern brass buttons and annual bluegrass emerged mostly in the fall and winter (Table 2). Summer annuals, common purslane and hairy nightshade emerged in the spring and summer. Burning nettle, common chickweed, common groundsel, henbit and shepherdspurse emerged throughout the year. Common purslane emerged 90 days after the biofix date when 219 hours of 10°C heat units had accumulated and hairy nightshade emerged 65 days after the biofix date when 452 hours of 4°C heat units had accumulated.

Reduced herbicide rates in summer-planted lettuce. The best herbicide treatment for all-around weed control efficacy in summer-planted lettuce at both the San Ardo and Chualar sites was pronamide plus bensulide at 0.75 plus 3.0 lb ai/A (Table 3). This treatment provides control of both hairy nightshade, a species not controlled by bensulide, and pigweed, a species not completely controlled by pronamide. Bensulide alone at 3.0 and 5.0 lb ai/A had very little activity on hairy nightshade or shepherdspurse, but was quite active on common purslane and pigweed.

A comparison of the brush hoe cultivator with a standard cultivator. The operation of the brush hoe is shown in Figs. 1 and 2. The main effects of brush hoe cultivation and standard cultivation were significant. Across all herbicide treatments the brush hoe provided 64.5% control of shepherdspurse and the standard cultivator provided 49.4% control (LSD 0.05 = 7.3%). A comparison of the weed control efficacy of the two cultivators, within herbicide treatments, revealed that pronamide at 1.5 lb ai/A and no herbicide (untreated check) resulted in significantly greater shepherdspurse control where the brush hoe was used versus the standard cultivator (Table 4). Lettuce thinning times were significantly lower in brush hoe cultivated plots where bensulide was applied at 3.0 lb ai/A and in the untreated check (Table 5). The brush hoe had no significant effect on lettuce stand compared to the standard cultivator (data not shown). The brush hoe had no effect on lettuce yield in any treatment except in the bensulide 3.0 lb ai/A treatment (Table 6). Lettuce treated with bensulide at 3.0 lb ai/A and cultivated with the brush hoe yielded significantly more than lettuce treated with the same rate of bensulide, but cultivated with the standard cultivator.

Discussion

Field emergence and seasonally adjusted weed control inputs. Weed populations changed by season at all sites. The pattern of weed emergence suggests that weed control inputs should vary by season and that a seasonally adjusted weed control program may provide equal or better weed control with reduced herbicide inputs. For example a winter weed control program for lettuce might be 0.75 to 0.94 lb ai/A pronamide in combination with the brush hoe cultivator. The use of bensulide in the winter would be unproductive since this herbicide is not active on most of the species present at that time. A summer lettuce weed control program based on pronamide plus bensulide at 0.75 + 3.0 in combination with the brush hoe would combine the strengths of both herbicides with the brush hoe to provide control of most weeds emerging at that time.

Summer weed management. Low weed pressures at sites such as San Ardo suggest that at some locations weed emergence in summer-planted lettuce may be so low that herbicide treatments need not be used at the full rate. The brush hoe cultivator was tested in a weedy field site, with weed pressure higher than most Salinas Valley fields, yet despite the high weed pressure the brush hoe performed well. The brush hoe cultivator may increase the level of weed control even when the herbicide rate is reduced. Additionally, based on the data from Table 5, the brush hoe cultivator reduced the number of hours per acre required to thin lettuce by 3.1 to 6.4 hours per acre.

Outreach. Monterey County Farm Advisor Richard Smith and the PI hosted a field day on 7.20.99, and some of the work described above was presented to about 40 pest control advisors, farmers and Cooperative Extension personnel. Acknowledgment of the California Department of Regulation was given. Mr. Smith and the PI demonstrated the brush hoe cultivator to a grower on 9.17.99. Additionally, Richard Smith and the PI met twice in May 1999 and once in July 1999 to discuss the implementation and results of this research. Richard Smith made presentations about the brush hoe to 80 grower and consultants on 11.30.99, and to 40 growers and consultants on 2.20.00. Two poster presentations of the results of this research were made at the Weed Science Society of America annual meeting February 6 to 9, 2000 in Toronto, Canada (see publications produced). A photo set of the brush hoe and reduced rate herbicide photo set has been taken. These photos are being used in extension education seminars, extension publications and at professional meetings.

Summary and conclusions

The objectives of this project are: 1) Develop an emergence model based on air and soil temperatures for common central coast weeds such as: burning nettle, common purslane, hairy nightshade, redroot pigweed and shepherdspurse, and 2) Develop a weed management program for lettuce based on reduced herbicide rates and improved cultivator designs. We have conducted two full seasons of research on this project and feel that we can make the following preliminary conclusions:

- We have begun to develop an emergence model for common purslane and hairy nightshade based on degree day accumulation.

- This project has demonstrated seasonal variation in weed emergence and germination potential. The significance of this finding is that weed management inputs in lettuce should vary by season. For example, we plan to recommend that bensulide not be used during December to February since weeds that it controls do not emerge during that time. This recommendation will help eliminate unnecessary expense to growers by minimizing the use of needless herbicide applications and also will minimize unnecessary applicator exposure.

- The brush hoe cultivator will allow cultivation very close to the lettuce seed line, thus uprooting most weeds. This implement may allow the use of reduced herbicide inputs without exposing the growers to high levels of economic risk.

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List of publications produced

Fennimore, S.A., X. Li, S.J. Richard, R.F. Smith. 2000. Optimized weed management inputs for California lettuce made according to seasonal fluctuations in weed emergence. Weed Science Society of America Abstracts 40: 39

Richard, S.J., S.A. Fennimore. 2000. A comparison of brush hoe and shovel cultivation weed control in lettuce. Weed Science Society of America Abstracts 40: 40

Appendix I. Tables

Table 1. Temperature[1] and light conditions in the growth chamber

From	to	Photoperiod[2]	Temperature(°C) Day	Temperature(°C) Night
21-Mar-99	20-Sep-99	6:30-20:00	25	18
21-Sep-99	05-Nov-99	7:00-18:30	25	6
06-Nov-99	20-Dec-99	7:00-17:00	20	5
21-Dec-99	03-Feb-00	7:00-17:00	20	-1
04-Feb-00	20-Mar-00	6:30-18:00	20	2

[1] approximate prevailing 5 cm soil temperatures at Salinas, CA, since 21 September 1999.
[2] coinciding with day-length of the median date of the period covered (i.e., 14 Oct., 29 Nov., 14 Jan., 28 Feb. for 21 Sep.-5 Nov., 6 Nov.-20 Dec., 21 Dec.-3 Feb., 4 Feb.-20 Mar. , respectively)

Table 2. Field emergence percentage by season of winter annuals (annual bluegrass and southern brass buttons), summer annuals (common purslane and hairy nightshade), and continuously germinating species (burning nettle, common chickweed, common groundsel, henbit, and shepherdspurse) in the Salinas valley. The percentage total sums to 100% for the 12-month period from 21 March 1999 to 21 March 2000.

		Seasonal percentage contribution			
	Sites	Spring	Summer	Fall	Winter
S. Brass buttons	Spence	0.1	0.0	13.1	86.8
Bluegrass	Salinas	0.0 (0.0±0.0)[a]	8.3 (4.0±1.3)	34.9 (57.0±5.3)	56.8 (47.0±4.0)
H. Nightshade	Spence	49.7	40.3	9.4	0.6
Purslane	Spence	12.8	87.2	0.0	0.0
Chickweed	Salinas	15.5 (4.0±2.0)	14.4 (16.0±2.0)	27.1 (44.0±10.0)	43.0 (21.0±2.0)
Chickweed	Spence	3.0 (2.0±2.0)	3.7 (0.0±0.0)	18.7 (56.0±16.0)	74.6 (37.0±21.0)
Groundsel	Spence	21.5	30.6	17.2	30.7
Henbit	Spence	19.5	12.6	23.8	44.1
B. Nettle	Salinas	27.5 (15.0±4.0)	15.1 (19.0±7.0)	15.5 (57.0±7.0)	41.9 (37.0±1.0)
Shepherdspurse	Salinas	26.7 (34.0±22.0)	15.8 (15.0±11.0)	21.4 (18.0±6.0)	36.2 (75.0±16.0)
Shepherdspurse	Spence	20.4	14.8	18.0	46.8

[a] Data inside parentheses are germinability as defined in the text.

Table 3. Number of common purslane, pigweed, hairy nightshade and shepherdspurse present per m² (10.8 ft²) of plant bed at San Ardo on 9.1.99 and Chualar on 9.8.99 in each herbicide treatment.

		San Ardo		Chualar	
Herbicide	Rate lb ai/A	Common purslane	Pigweed	Hairy nightshade	Shepherdspurse
pronamide	0.75	8.9 B	4.8 B	33.2 AB	26.8 AB
pronamide	1.5	3.0 B	2.2 C	53.9 AB	15.5 B
bensulide	3.0	0.3 B	0 C	130.4 A	41.5 A
bensulide	5.0	0 B	0 C	59.9 AB	25.7 AB
pronamide + bensulide	0.75 + 3.0	0 B	0 C	22.6 B	27.9 AB
untreated check	--	29.6 A	8.6 A	66.0 AB	26.0 AB
LSD 0.05		11.2	2.5	93.8	18.9

Table 4. Differences in shepherdspurse control resulting from the brush hoe and the standard cultivator in combination with pronamide and bensulide treatments. The percent weed control was calculated using the equation $[(B-A)/B]100$ where B = the number of weeds per 2,652 cm^2 before cultivation, and A = the number of weeds per 2,652 cm^2 after cultivation. The before and after counts were both taken at the same location within each plot.

		Percent control		
Herbicide	Rate lb ai/A	Brush hoe	Standard	Difference
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
pronamide	1.5	78.5	54.8	23.7 *
bensulide	3.0	64.8	48.6	16.2
bensulide	5.0	60.8	54.5	6.3
pronamide + bensulide	0.75 + 3.0	54.0	43.6	10.4
untreated check	--	65.1	43.7	21.4 *
LSD 0.05				18.5

* Significantly different at P = 0.05 for comparisons across cultivators but within an herbicide rate.

Table 5. Differences in lettuce thinning time in seconds per 12.2 m^{-1} (40 ft) of row resulting from the brush hoe and the standard cultivation treatments used in combination with pronamide and bensulide treatments.

		Lettuce thinning time (sec./ plot)		
Herbicide	Rate lb ai/A	Brush hoe	Standard	Difference
pronamide	0.75	74.0	91.3	-17.3
pronamide	1.5	61.9	82.2	-20.3
bensulide	3.0	73.9	109.3	-35.4 *
bensulide	5.0	75.5	95.4	-19.9
pronamide + bensulide	0.75 + 3.0	69.8	93.5	-23.7
untreated check	--	84.5	118.8	-34.3 *
LSD 0.05				26.6

* Significantly different at P = 0.05 for comparisons across cultivators but within an herbicide rate.

Table 6. Differences in lettuce yield per 3.1 m^{-1} (10 ft) of bed resulting from the brush hoe and the standard cultivation treatments used in combination with pronamide and bensulide treatments.

		Lettuce yield (kg 3.1 m^{-1})		
Herbicide	Rate lb ai/A	Brush hoe	Standard	Difference
pronamide	0.75	10.8	11.9	-1.1
pronamide	1.5	10.6	10.8	-0.2
bensulide	3.0	12.7	9.8	2.9 *
bensulide	5.0	10.2	10.9	-0.7
pronamide + bensulide	0.75 + 3.0	9.6	11.2	-1.6
untreated check	--	11.2	11.6	-0.4
LSD 0.05				2.2

* Significantly different at P = 0.05 for comparisons across cultivators but within an herbicide rate.

Fig 1. Rear (left) and side views (right) of the brush hoe cultivator from the 1999 Salinas valley lettuce evaluation.

Fig 2. Lettuce beds are shown before (left) and after (right) cultivation with the brush hoe.